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# PARTICULARITIES OF HEATING GLASS BY A MULTIPOINT ENERGY SOURCE

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A mathematical model based on the principle of the superposition of waves is proposed for the power distribution on the surface of a glass plate heated by means of tubular heaters. This model makes it possible to predict the propagation of the temperature field on the surface of glass plate as a function of the arrangement and power of the heating elements.

***Key words:*** glass, heating, mollification, temperature, power.

Heating glass is the most important part of the industrial processing of sheet glass. The parameters of this process have a critical affect on the quality and cost of the finished part.

When new equipment is being designed, especially for small and medium enterprises, which are mainly focused on mollification and hardening of glass, the minimum energy consumption with all quality indicators being preserved must be taken into account. One of the quality indicators for heating glass is uniformity of the temperature distribution in the heating zone. Since the temperature distribution in the glass is formed by heat transfer along layers, the variant of heat delivery to the glass surface, i.e., the power distribution, becomes critical. Initially, the temperature distribution over the surface will depend strongly on this indicator. For this reason, determining the dependence of the power on the configuration and power of the heating elements is an important element in determining the structural parameters of a furnace.

Since glass is heated primarily (85%) by infrared radiation, i.e., radiation with wavelength ranging from 1 mm to 770 nm [1], we shall use the wave theory to determine these parameters. The heating elements are represented as tubes. Since the size of these elements is much smaller than their distance from the surface of the glass, we shall represent them as points to simplify the calculations.

The calculations are performed in a sequential order which is based on the principle of the superposition of waves. Consequently, we shall perform the calculations for the following cases: power distribution produced over the surface of a glass plate by two, three, and six heaters.

Power propagates from the source to the glass surface according to the law of power transfer by radio-electronic waves [2]:

$$P = P_0 e^{-r\gamma},$$

where $P_0$ is the initial power; $r$ is the distance to the heated object; and, $\gamma$ is the total absorption coefficient.

We shall examine the heating of a glass plate of length $L$ by several heaters (Fig. 1).

Let us analyze the formation of a temperature field on the surface of the glass plate. If the power delivered at the point $C$ on the surface of the glass plate is taken to be 1, then it is necessary to determine the functional dependence of the decrease of the power on the surface of the plate as function

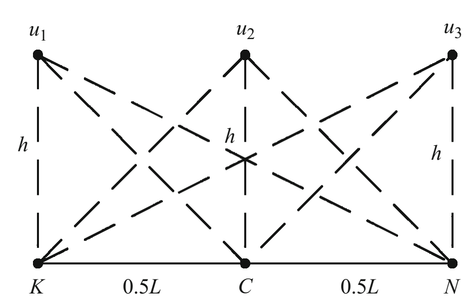


**Fig. 1.** Geometric parameters of the heating of glass by several heaters: $u_1$, $u_2$, and $u_3$ ) radiation sources; $L$ ) length of the heated plate; $h$ ) distance to the radiation sources.

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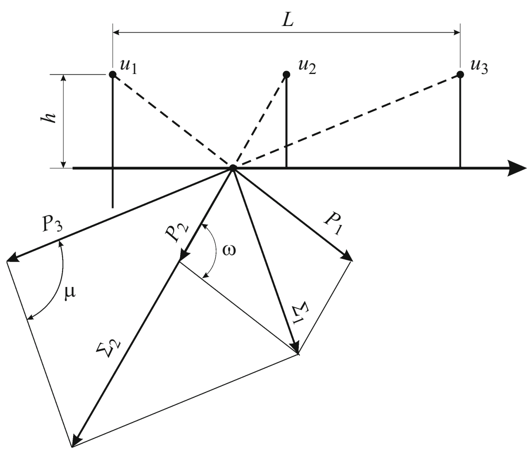


**Fig. 2.** Geometric interpretation of the addition of the power vectors of the radiators at the point $x_i$ on the surface of the glass plate.

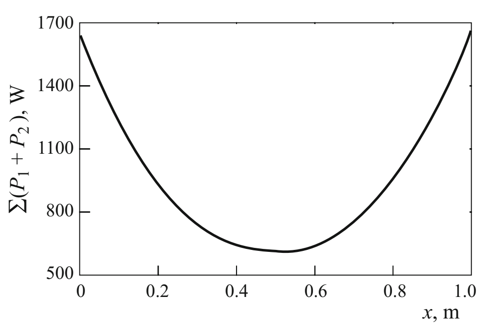


**Fig. 3.** Power distribution produced over the surface of a glass plate by two heaters.

of the distance from the periphery of the plate. For this reason, using the method of superposition, we sum the power at an arbitrary point $x_i$. To construct plots of the power distribution on the surface of the plate equations for the indicated point within the confines of the plate, i.e., from 0 to $L$, must be obtained.

For this we shall use the scheme shown in Fig. 2.

The total power at the point $x_i$ from two heaters is

$$\sum(P_{1x} + P_{2x}) = \sqrt{P_{1x}^2 + P_{2x}^2 - 2P_{1x}P_{2x}\cos\omega},$$

where $P_{1x}$ and $P_{2x}$ are the initial powers from the first and second heaters, respectively, and ù is the angle between the projections of the vectors from the first and second heaters.

We shall now construct a plot of this function for the following parameters: $h = 0.15$ m is the distance to the source of radiation; $L = 1$ m is the length of the plate; the absorption coefficient $\gamma = 0.65$ [3]; $P_1 = P_2 = 1.5$ kW is the initial power. The total power from two sources of radiation will be 3 kW. As a result, we obtain the plot shown in Fig. 3 for the power distribution produced over the surface of the glass plate by two heaters.

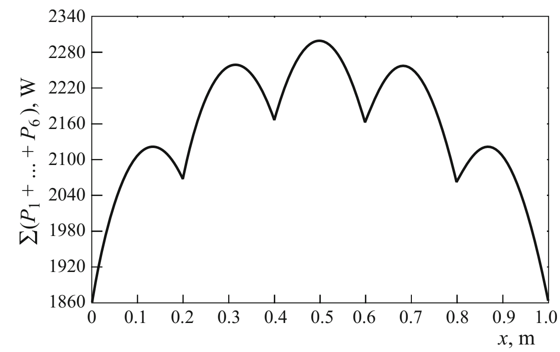


**Fig. 4.** Power distribution produced on the surface of a glass plate by six heaters.

A sharp drop in the power consumption is observed at the center of the plate. The drop is 36.9% relative to the maximum value.

Such a construction is unlikely in practice. As a rule, multi-element heating is used. For this reason, we shall calculate the power drop on the surface of the plate for a three-component heating zone. The total power of these three radiators will also be 3 kW, i.e., $P_1 = P_2 = P_3 = 1$ kW.

The total power produced at the point $x_i$ by three heaters will be

$$\sum(P_{1x} + P_{2x} + P_{3x}) = \sqrt{\sum(P_{1x} + P_{2x})^2 + P_{3x}^2 - 2\sum(P_{1x} + P_{2x})P_{3x}\cos\mu},$$

where $P_{3x}$ is the initial power from the third heater and μ is the angle between the projections of the vectors from the third heater and the total power from the first and second heaters.

Finally, we obtain the following equation for the coefficient of power decrease at the point $x_i$ on the surface of the glass plate:

$$\Omega_x = \frac{\sqrt{\sum(P_{1x} + P_{2x})^2 + P_{3x}^2 - 2\sum(P_{1x} + P_{2x})P_{3x}\cos\mu}}{P_0 e^{-\gamma h}},$$

where $\Omega_x$ is the coefficient of power decrease.

We shall now consider the power produced on the surface of the plate by six sources of radiation (Fig. 4). The total power of these sources will be 3 kW.

The equation for the total power produced at the point $x_i$ by six heaters will have the following form:

$$\sum(P_{1x} + \ldots + P_{6x}) = \sqrt{\sum(P_{1x} + P_{5x})^2 + P_{6x}^2 - 2\sum(P_{1x} + \ldots + P_{5x})P_{6x}\cos\delta},$$

where $P_{6x}$ is the initial power due to the sixth heater; $\Sigma(P_{1x} + \ldots + P_{5x})$ is the total power due to five heaters; and, δ is the angle between the projections of the vectors from the sixth heater and the total power of the five heaters.

The analysis performed above has shown that an increase of the number of heaters, all heaters having the same power, gives a positive effect: a uniform distribution of the power on the surface of the glass plate, and there are no excursions above the maximum admissible power at a concrete point on the plate. This makes it possible to place at different points heaters with different power, making it possible to vary the power distribution curve even more and to control the heating at a concrete point on the plate.

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